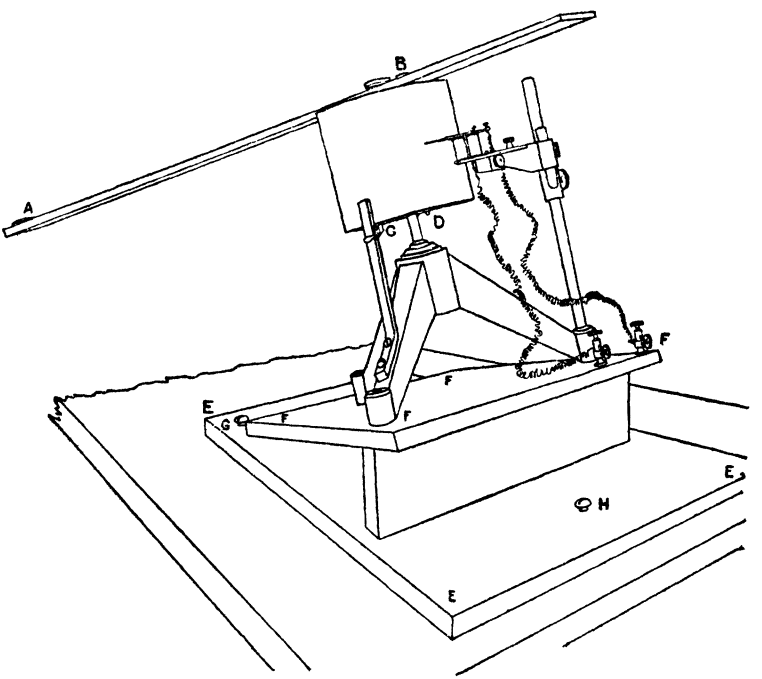
A NEW PENDULUM CHRONOGRAPH.

By Edmund C. Sanford, Ph. D.



An instrument like that shown in the rude sketch above has been used for two years in the practice work in this laboratory, and as it has proved itself simple and easy to use and tolerably accurate, a description of it may be of interest. In principle the instrument is simply a pendulum swinging completely around in an inclined plane, with a writing surface bent around its axis. This arrangement has two advantages over the ordinary pendulum myograph: the pendulum has no backward swing, and the tracing made by the writing point is a straight line and not a curve.

The instrument was made by fastening a wooden bar upon the top of a "students' drum" of the Cambridge Scientific Instrument Company's pattern, and screwing down the whole on a slightly inclined surface. This bar, lettered *A B* in the cut, has a total length of 1.22 m., a width of 6.4 cm., and a thickness of 1.2 cm. The bar is pierced with a hole 32 cm. from the upper end, which fits snugly about the base of the knob on the top of the drum, and is faced with brass at this point to prevent its wearing loose. The bar is held in place by a thumb-screw (lettered *B*), that passes through into one of the spokes of the drum, and allows the removal of the bar when the drum is to be smoked. A small bob made of two brass plates and weighing 170 grms. is fastened 7.6 cm. from the end of the rod. The drum itself is 13.3 cm. high and 16.1 in diameter, and turns smoothly and easily about a central spindle, a portion of which is visible below it. The inclined base on which it stands is 40.7 cm. long by 38 cm. wide, and makes an angle of 14° with the horizontal base below. In the latter are set three leveling screws, two at the back, one in front, for adjusting it to the horizontal; two of these, lettered *H* and *G*, are shown in the cut.

To secure uniformity in the swings, the pendulum always starts from the same point, *i. e.*, from the catch, lettered *C* in the cut. When the pendulum is ready to fall the peg *D* rests against the catch and the pendulum rod extends upward and to the left. When the pendulum is released, it falls to the left, passes its central point and rises again on the right to a position where it is easily caught with the right hand and carried on again till the peg once more rests against the catch, and everything is ready for another fall.

The time to be measured is inscribed on the smoked paper surface of the drum by a writing magnet. A rack and pinion may be used for raising or lowering this, as shown in the cut, or it may be made to fit tight enough on the post to stay where it is put, as in the instrument in this laboratory.[1]

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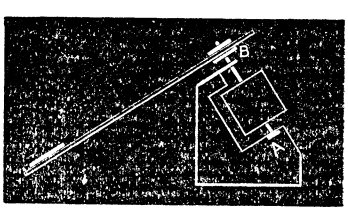
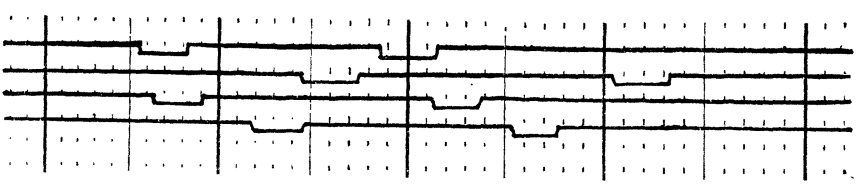
[1] A few tests were made at the start with a still simpler apparatus. This was nothing more than a wooden cylinder, about three inches in diameter, with a steel rod running through it, with a point at the bottom and a collar and nut at the top for attaching the pendulum bar, something as shown in the cut in the margin. The point of the rod rested in a little hollow in a bit of brass at *A*, and was supported by a Y of brass at *B*. The results showed a considerable degree of acuracy.



In order that such an instrument should give accurate results, two things must be regarded: the successive swings of the pendulum must be made in equal times, and the inertia of the writing magnet must be known or compensated. In a recent test of twenty-four successive swings of the pendulum, made just after oiling the spindle, there was a gradual change in the time required for the pendulum to traverse a marked space, corresponding to a little more than a second of time in the middle of its swing, of about .002 sec. Other tests, however, gave less favorable results. In 190 swings, taken ten days later without re-oiling, each tenth swing being timed, the extreme difference reached .009 sec.; but in a third set of 13 consecutive swings, taken on another occasion after re-oiling, it fell again to .003 sec. The difference from set to set, due perhaps to differences in leveling or lubrication, was greater than these, amounting to .018 sec. between the fastest swing measured and the slowest. An error from this cause might perhaps reach one part in fifty between single selected swings, but with care could probably be kept much smaller, and in an average at all events would certainly be so. This error is also distributed over a considerable portion of the swing, and is smaller absolutely when shorter intervals are measured.

The error of the magnet could be measured upon the drum itself by arranging for the making and breaking of an electric circuit at a fixed point by the motion of the drum, but it is simpler to exclude the error by using the same movement of the armature of a single magnet to indicate both the beginning and end of the time to be measured, as indicated in the cut below. This is accomplished without difficulty by put-



ting the beginning and ending keys in parallel circuit and letting the closure of the first be shorter than the time to be measured. In case the presence of a constant error is unimportant, as, for example, in reaction-times, where relative results are aimed at, the use of the magnet may still further be simplified by making the closure of the circuit correspond to the beginning of the time to be measured and its opening

with the end. The error introduced is the difference between the inertia of the magnet at the make and its inertia at the break. If a Deprez signal is used as a time-marker, this difference should not exceed .003 sec. and with careful adjustment would be practically zero.

A defect of such an instrument is that it does not move evenly throughout a swing, but first slowly, then rapidly, and at last slowly again, so that a given distance on the surface of the drum does not everywhere mean the same amount of time. The simplest way to obviate this is to accompany the time tracing with a parallel tuning-fork tracing, but this requires a laborious counting of the waves in the latter. An easier way, when the successive swings are tolerably uniform, as in this instrument, is to take one tuning-fork tracing, make it permanent, and stick it, taking care not to stretch the paper, on the edge of ruler. When this has once been counted and marked off, it can be applied to any time tracing and the amount read off, at once. A still more expeditious way (used already by Dr. Bowditch upon pendulums) is to have the scale printed directly on the paper with which the drum is covered. If the drum is lightly smoked the lines of the scale can be seen through the blackening and the time tracing read at once in units of the scale, and by estimate to a tenth of one of them.[1] In the cut above a portion of such a scale is shown; the finest divisions give hundredths of a second directly, and thousandths by estimate. An intelligent engraver can cut a block for printing a scale of this kind from a tuning-fork tracing taken with a Deprez signal or other time-marker; but he should be cautioned with regard to accuracy, and especially to get the scale lines exactly parallel, otherwise another error is introduced. An error is also apt to creep in in the estimate of tenths, but should not amount to more than one-tenth, so that the total error of any single measurement, provided the scale is exact, ought not to exceed three or four thousandths of a second for short times, and one part in fifty for times of a second or over, a degree of accuracy that is sufficient for all practice work in psychological time measurements and for many kinds of research.

This kind of a chronograph lends itself easily to measurements of any time intervals less than about two and a half seconds; the time of a whole swing is nearly four seconds, but the scale is so crowded at the ends that they are practically useless. Anywhere in the middle second of the swing

[1] When the record has been read the paper need not be removed from the drum, but may be wiped off and resmoked, and this may be repeated a number of times.

the scale is open enough to admit of estimating tenths of a division. All the ordinary reaction- and association-time experiments fall below this limit, and the instrument is useful for that sort of experiment because it is nearly noiseless.

The chronograph can readily be adapted for other time experiments. If two break circuit keys are arranged so that they may be opened by the turning of the drum, Exner's interesting experiments on nearly simultaneous sensations in different senses can be repeated, and the drum itself can be used to measure the time between the stimuli, while at a few minutes' notice these fittings and those for the chronograph can be removed and the drum restored to its original purposes.

If the laboratory already has a drum, writing magnet and electrical tuning-fork, as most with full equipment have, the expense of setting up the chronograph (aside from the block for printing scales, which should cost from 10 to 15 dollars) is not great; if these have to be bought new the instrument will cost between 40 and 50 dollars.